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THE BLOOD-CORPUSCLES OF THE ANNELIDES. By Professor ROLLESTON, M.D., F.R.S.

PROFESSOR LANKESTER, in a recent number of the *Quarterly Journal of Microscopical Science*[1] (January 1878, p. 70–73), makes certain statements relating to me, the chief tangible basis for which is the following quotation from p. cxxix. of my *Forms of Animal Life*, published in 1870 :—"In a few Annelides, again (*Syllidea armata*, the *Opheliæ*, the *Cirratulida*, and the *Staurocephala* and *Branchiobdella*), the pseud-hæmal system contains corpusculated blood, and communicates with the perivisceral

[1] Professor Lankester writes as follows :—"The entirely original introduction of *Branchiobdella* into the list of Annulata with corpusculated 'pseud-hæmal fluid' is difficult to explain, since, from what follows, it seems unlikely that Dr George Rolleston had made himself acquainted, by actual observation, with any of the genera to which he alludes. On page 238 of the second edition of Gegenbaur's *Grundzüge*, a somewhat awkwardly introduced reference to Dorner's paper on *Branchiobdella* might lead an unwary reader to suppose that the statements there given on the authority of Kupffer and Leydig, with reference to the proliferation of blood-corpuscles from the valves of the vessels in other leeches (*Piscicola* and *Clepsine*), have reference to *Branchiobdella*, which they have not. A glance at Dorner's excellent memoir on *Branchiobdella* would, however, suffice to satisfy a conscientious bookmaker that the vascular fluid of *Branchiobdella* has not yet been shown to contain corpuscles, and that it notoriously differs from the vascular fluid of true leeches, in that it most certainly does not 'communicate with the perivisceral cavity so as to form a lacunar circulation.' The introduction of *Branchiobdella* into the list given by Dr George Rolleston is, it would seem, due to his having misunderstood the German authors. The statement that 'the pseud-hæmal system communicates with the perivisceral cavity so as to form a lacunar circulation in *Syllidea*, the *Opheliæ*, the *Cirratulida*, and the *Staurocephali*' is more difficult to account for than is that relation to *Branchiobdella*, since whilst there is here no foundation whatever for such a statement in fact, the description and figures of Claparède with reference to two at least of these genera are admirable in clearness and detail. We are driven to the conclusion that Dr George Rolleston has acquainted himself with the introduction without having consulted the body of Claparède's work. . . . . Whilst I regret to find myself unable to accede to the statements in the text-book which I have quoted above, I may point out that the errors therein contained are not traceable to any attempt on the author's part to make original observations in the domain of morphology, but are rather due to a failure to observe accurately the contents of books." It will be observed that while some of these statements relate to matters of fact, and others to matters of inference based upon facts, or supposed facts, a third set consists mostly of expressions of Professor Lankester's personal opinions. I shall deal only with the two former sets of statements.

cavity so as to form a lacunar circulation." In answer to Professor Lankester's attack, I have to say, that a careful consideration of the passage just quoted, and even *as* just quoted, that is to say, isolated and apart both from the connection in which it stands, and from discussions of the same subject elsewhere in the same book, is sufficient to suggest to any unprejudiced observer that the error which it contains is simply an error of the press. The passage should run, as by a most trifling and obvious transposition and alteration it can be made to run, thus:—"In a few Annelides, again (*Syllidea armata*, the *Opheliæ*, the *Cirratulida*, and the *Staurocephali*), the so-called pseudhæmal system contains corpusculated blood, and *in Branchiobdella* communicates with the perivisceral cavity, so as to form a lacunar circulation." As regards the passage when thus altered, I shall hereafter attempt to show that it states what is currently accepted as our knowledge of the subject. But I have first to prove that, as it stands in the book, it should have suggested to Professor Lankester that it should be thus manipulated and altered. Taking then the passage as it stands, and as isolated, I will ask the candid reader to note the eleven words contained in brackets, and particularly the last five of them. He will observe that a comma is placed after each of the three sets of words, "*Syllidea armata*," "the *Opheliæ*," "the *Cirratulida;*" that to these three sets of words a fourth similar set is added in the words, "and the *Staurocephali*," to which no comma is appended; and finally, that to this fourth set of words, denoting a fourth set of Annelides, a fifth set is added in the awkward set of words, "and *Branchiobdella*." Surely the clumsy repetition of the particle *and* might have been considered to indicate that something was wrong in the sentence, and when combined with the fact that no comma is placed after "*Staurocephali*," must show that this latter word had somehow or other got dissevered from the terminal comma-superseding hyphen, by an accidental intercalation into the space left vacant above of the words "*and Branchiobdella*." These two words should be slightly altered into "*in Branchiobdella;*" and secondly, slightly transposed, so as to take their place between the next "and" and the word "communicates." Of the adequacy of this argument any conscientious critic can judge without troubling himself to consider the context

in which the passage in question stands, or the two other portions of my book in which the subject is treated, and indeed without special knowledge of the matter at all. To proceed synthetically: I will add that anybody who will write the statement out in lines of eight words each or thereabouts, *omitting the words* "and *Branchiobdella*" from those lines, and will then add them in his MSS. with the customary Greek lambda-λ-like note placed interlinearly, will be amused to see how easily the supplemented words come within the grasp of the embracing hyphens. Unfortunately, even for my own satisfaction, I allowed my MSS. of *Forms of Animal Life* to be destroyed only quite recently; the printed proofs, happily, I still preserve. Commas and hyphens are, it is true, not anatomical or natural history facts, but they are facts of human history, and if looked at carefully, will furnish a scientific observer with as sure a clue to the interpretation of a man's intention as the observation of the actions of one of the lower animals will do as to the interpretation of its meaning on any particular occasion.

Having thus, in the first place, appealed to the judgment of scientific men of every class; that is to say, to the judgment of all fair judging men who will take the pains to attend to all the circumstances of a very small question; I will, in the second place, adduce some evidence, the appreciation of which does require some special knowledge of the subject, being based upon a consideration of the passage, in connection with its context and its obvious meaning. Anybody who will read that part of my chapter on the sub-kingdom Vermes, from p. cxxii. to cxxxi., which relates to the "class Annulata proper," will see that on p. cxxix., the page containing the passage which Professor Lankester has taken for his text, the word "Annulata" is used no less than four times, and obviously and expressedly as inclusive of the Discophora. The likeness indeed of *Branchiobdella* to the *Naidea* had been hinted at by both Grube, in 1851 (*Die Familien der Anneliden*, p. 115), and Claparède, in 1868 (*Bibliothèque Univ. de Genève*, N.S. xxii. p. 348); but no one had in 1870 proposed, as Gegenbaur has subsequently (*Grundriss*, 1878, p. 134), to consider *Branchiobdella* one of the Oligochæta rather than one of the *Hirudineæ*. I submit, therefore, that I am justified in saying that my readers, on finding the word "Annelides" used

once on a page in which the word "Annulata" is used several times, might have been expected to suppose that the former word was not used in the same sense as the latter; and the more so as this different and restricted sense is the very sense in which it is used by both Leuckart (*Menschlichen Parasiten*, p. 155, 1863) and Gegenbaur (*Grundzüge*, p. 159, *et alibi*, 1870), the two authors to whose pages I had most constantly referred.

I will now ask the reader to refer to a somewhat wider context, and, turning to a note on p. 138, to observe that there, in opposition to the nomenclature of the two last-cited authorities, and also of De Quatrefages, I argue at some considerable length in favour of connecting the Hirudineæ with the Annelides. The Introduction to my book was written after the other two parts; and in the corrected proofs now before me, I find that I have, it may be charitably supposed with a view of saving the student from confusion, throughout the part in question altered the word "*Annelides*," which I had written and had before me in print, to "*Annulata*," whenever it had been intended to be used in the wide sense in which Lamarck, Milne-Edwards, Grube, and Leydig use it, and I myself, as the note in question proves, should have preferred to use it, and indeed do use it at pp. 122, 135, 138, so as to include both Discophora and Chætophora. I do not blame my readers for not having consulted printed proofs which were not accessible to them; persons, however, to whom an inner conviction of their own accuracy may be dear in the face of adverse criticism, may learn from this the advisability of preserving such documentary evidence as that to which I have here referred.

Leaving now the very wearisome and somewhat unprofitable task of self-vindication, I will now proceed to point out that several of Professor Lankester's statements are in opposition, not only to the authorities, but also to the facts of the case.

The first of these statements with which I will deal is to the effect that "the vascular fluid of *Branchiobdella* notoriously differs from the vascular fluid of true leeches, in that it most certainly does not *communicate with the perivisceral cavity so as to form a lacunar circulation*." The words I have italicised are quoted from my book; but I did not speak of blood, but of blood-vessels, as combining with another blood-carrying cavity. This, how-

ever, is mere verbal criticism. What are the facts of the case? *Branchiobdella* is an animal which, so far as I know, never exceeds ½ inch in length, and which, for a satisfactory examination of its internal organs, needs to be rendered transparent by lying some days in acetic acid and subsequently in glycerine. When examined whilst alive under the microscope, Dr Dorner (*Zeitschrift Wiss. Zoologie*, xv. p. 479, 1865) tells us that the observation of its circulation is made exceptionally difficult by the fact that the dorsal vessel in the posterior part of its length is very closely apposed to the digestive tract, and whilst its walls are in this non-contractile portion of its length extremely thin and transparent, the digestive tract, on the other hand, is dark coloured. In the larger of the two species, *Branchiobdella parasita*, it is true, Dr Dorner says the intestine has a less dark colouration, and that it is possible in it to make out clearly the course of the dorsal vessel, especially if the animal is kept a long time under the covering-glass, and subjected to gentle pressure. The pressure, I will remark, must be very gentle indeed, if it is not to introduce a source of fallacy into such an investigation as this; and this consideration may well make us hesitate before accepting in their entirety, and in the strict sense which the author himself contemplated, the following words of Dr Dorner (p. 499 *l. c.*):—"Das gesammte Blutgefass-system des Korpers steht so mit im unmittelbaren Zusammenhange, und stellt einen vollstandigen Kreislauf dar." I may illustrate this matter further by referring to the disputes which were raised in former days as to the existence or non-existence of an orifice of communication between the anterior or exteriorly opening sac of the organ of Bojanus and the secretory part of the organ even in animals of the size of our fresh-water mussels, where the difficulties of being quite sure as to one's ground were by no means so great as in this case. *Branchiobdella*, however, has not, so far as I have been able to find, been as yet met with in the parts of the United Kingdom with which I am acquainted, illustrating therein the well-known natural history law of the partial, and to us often inexplicable, distribution of parasitic organisms, to the life of which, and consequently to the diseases produced by which, other conditions are often necessary besides that of the presence of their hosts. (See Professor Klebs, *Vortrag ueber die Umgestal-*

tung der Medicinischen Anschauungen, 1878, p. 52–53, as regards Lepra.) It finds no place in the *British Museum Catalogue of Worms*, by Dr George Johnston, 1865, nor in Mr Edward Parfitt's *Catalogue of the Annelides of Devon*, published in 1878 (*Trans. Devon Assoc. Science, Literature, and Art*). Mr W. H. Jackson, Demonstrator of Anatomy in the Oxford University Museum, has often looked for it upon the numerous *Astaci* which are dissected here every term under his guidance, but in vain. I myself, and others elsewhere, have been equally unsuccessful; and though our examinations of the gills have been often rewarded by the sight of the beautiful *Cothurnia Astaci*, I doubt whether it has been the good fortune of other investigators to meet with this animal, apparently so common on the Continent, within our four seas, or at any rate in these southern counties. Hence I have been obliged to content myself with the plates and descriptions given by Odier and Henle (*loc. cit.*); by Keferstein, (*Archiv. Anat. und Phys.* 1863, p. 509); by Dr Dorner (*loc. cit.*); and, above all, with the statements of Leuckart and Leydig relating to it, the omission of the two latter of which names from a list of the authorities upon this subject appearing to me to be about as singular a proceeding as would be the omission of the names of Podalirius and Machaon from a list of the doctors in the *Iliad*. Inaccessible though the animal has been to me in the fresh state, and though the difficulties besetting much of its anatomy are such as to make it more than ordinarily hard to prove a positive, not to say a negative, conclusion respecting it, the animal nevertheless possesses very considerable claims upon the attentive consideration of the classificatory zootomist, being, as it is, an annectent form between the Hirudineæ and the Oligochæta. And as the peculiarities of its structural arrangements are specially interesting to those who, like myself (see note, p. 138, *Forms of Animal Life*), would unite the two families together with the Polychæta under the common term "Annelides," as a class name,[1] a glance at the plate of figures of this parasite,

[1] The question as to the propriety of ranging the Hirudineæ or Discophora in the same *class* even with the Chætophora has been perpetually raised even down to entirely recent times. Grube, in his excellent memoir on "Die Familien des Anneliden" (Wiegman's *Archiv.* 1850, S.A. p. 1), writes thus:—"Ein jeder, der von Anneliden handelt, eine Erklärung schuldig, ob er sie in dem Sinne von Cuvier, von Milne Edwards, Burmeister, Wiegmann oder R. Leuckart nimmt,

given in Odier's well-known paper in the *Mémoires. Soc. Hist. Natur.* (Paris, i. p. 70, 1822), show that its claims to be allowed to remain in the separate family with the animals of much the same unlovely habits and external form as itself are not lightly to be set aside on the score of their being based simply on teleological adaptations, whilst, on the other hand, the memoirs of Henle (Müller's *Archiv.* 1835, p. 574) and of Dorner (*loc. cit.*), dealing as they do with many important points of the internal anatomy only imperfectly handled by the first-named authority, do certainly lend some support to the opposite view of its affinities, —a view which, as already stated, Gegenbaur, in the last edition (1878) of his *Grundriss der Vergleichenden Anatomie* (p. 134), supports.

My statements as to the existence of corpusculated blood in the vascular system of *Branchiobdella*, and as to the communication of that system with its large perivisceral cavity were based,

und vor allem, ob er die Hirudineen mit ihnen verbinden oder zu den Planarieen (Dendrocoelen, Rhabdocoelen) und Trematoden hinüberführen will." It is true that Leuckart does (*Menschl. Parasit.* i. p. 156) put the Hirudineæ together with the other orders, the Turbellarians, Cestodes, and Trematodes, into a class "Platodes," which he keeps separate from a class "Annelides," containing the four orders, Acanthocephali, Nematodes, Chætognathi, and Chætopodes. He appears to me, however, to have done this rather for purposes of convenience as a helminthologist than as a zoologist; at any rate in the *Lehrbuch der Zootomie*, published in 1847 by himself and Professor Heinrich Frey, the Hirudineæ, *s.* Abranchiati, are ranged as a sub-order under a sub-class "Annelides," and in the *Menschlichen Parasiten* (p. 673) itself, we find this excellent authority, after specifying the points of similarity which subsist between the leeches and Trematodes as regards their reproductive system, saying:—"Die Aehnlichkeit mit den Trematoden, die wir so eben hervorhoben, erstreckt sich übrigens keineswegs bis auf die Einzelnheiten der anatomischen Bildung. Es finden sich hierin vielmehr so zahlreiche und durchgreifende Unterscheide, dass sich der Typus der Hirudineen auch in dieser Hinsicht als ein selbstständiger zu erkennen giebt." Claus, in the last edition (1876) of his *Grundzüge der Zoologie*, having in view, I apprehend, not only the utterances of Professor Leuckart, but also the discussions which had taken place between Claparède and De Quatrefages (*Bibliothèque Universelle de Geneve*, N.S. vol. xxii. 1865; *Bull. Sci.* p. 346; and *Annales des Sciences Naturelles*) upon this subject writes as follows (p. 395):—"Man hat daher neuerdings zumal im Hinblick auf die nahe Verwandtschaft mancher Discophoren und Polystomeen die Anneliden als systematische Einheit ganz aufgegeben und die Auflösung derselben in gegliederte Plattwürmer und gegliederte Rundwürmer befürwortet, allein einerseits erscheint der Anschluss an jene niedere Wurmclasse keineswegs auf die gesammte Organisation durchgreifend, andererseits gerade in dem gemeinsamen Charakter der Segmentirung ein so wesentliches die höhere Lebensstufe bedingendes Merkmal gegeben, dass wir den Verband der Anneliden als wohl gegründet betrachten."

and are still based, mainly, though not exclusively, upon Leuckart's account of these systems in this animal and some of its allies at pp. 651, 652, 665, 670 of the first volume of *Die Menschlichen Parasiten*, published in 1863. It would take too much space to reproduce these valuable pages here; most of them are referred to in *Forms of Animal Life* (pp. 138, 140), and Professor Lankester's phrase that the vascular fluid of *Branchiobdella* "*notoriously* differs," &c., has suggested to me, among other things, that it will be more than sufficient for my purpose to show from references to the utterances of the various writers who have referred to the matter subsequently to the appearance of Leuckart's work, that, as regards "notoriety," *Branchiobdella* is "notoriously" taken as the typical "text-book" illustration of the points which I specify.

Firstly, then, Professor Oscar Schmidt, well known to English readers as the author of *The Doctrine of Descent and Darwinism*, in the fifth edition of his *Handbuch der Vergleichenden Anatomie* (1865),[1] writes as follows with reference to the circulatory system of the Hirudineæ:—"The Discophora manifest the most remarkable relations, as it is only in *Branchiobdella* that the perivisceral cavity presents itself as an actual roomy cavity, with which the single large vessel running above the intestinal canal communicates." This statement is repeated in the sixth edition (p. 108), word for word, except so far as the substitution of the word "Egel" for "Discophoren" makes a difference.

Professor Claus, in the first edition of his *Grundzüge der Zoologie* (1866), in which (p. viii.) he expressly acknowledges the assistance given to him by Leuckart, has the following passage in a page (p. 155) where Leuckart's researches upon the circulatory system

[1] It will furnish encouragement, perhaps, to lecturers just entering upon their first course of Comparative Anatomy Lectures to read the following passage prefixed to this edition of Professor Oscar Schmidt's *Handbuch*. Persons who are as little liable to discouragement may, *ceteris paribus*, hope ultimately to attain to an eminence as great as that of the now deservedly well-known Professor. His words are:—"In Sommer Semester 1849 las ich zum ersten Male in Jena über vergleichenden Anatomie. Von den drei Wissbegierigen welche sich gemeldet war der eine schon mit der ersten Stunde befriedigt, und war nicht mehr gesehen. Die beiden anderen bezeigten mir ihre Sympathie bis zum Schluss; nie schwänzten sie zugleich. Das war für dieses Buch sehr wichtig, denn aus den fleissigen Vorbereitungen zu jenem Collegium und unmittelbar aus diesen ersten, oft in ein Zwiegespräch übergehenden Vorträgen enstand es."

of the Hirudinei are specially referred to:—"Am einfaehsten verhalt sich *Branchiobdella* mit einem contractilen Rückengefäss und einem in vordern Korperstück durch Schlingen mit dem erstern in Verbindung stehendem Bauchgefässe. Dieses scheint mit der weiten Leibeshöhle zu communiciren und aus derselben das Blut zu beziehen welches durch seine contraetile Wandung nach vorn getrieben wird." This statement is exaetly reproduced at p. 398 of the third edition of Professor Claus's work, which appeared in 1876.

Similarly, Professor Pagenstecher, at p. 373 of his *Allgemeine Zoologie*, Zweites Theil, 1877, writes:—"Leuckart meint es möge der Rückenstamm, welcher schon 1719, Dillenius bei den Blutegel beschrieb, mit der bei *Branchiobdella* unter den Hirudineen besonders weiter Leibeshöhle in offener Verbindung stehen, seinen Inhalt aus letzterer beziehen, die in der Leibeshöhle auf und abtreibende Flussigkeit schon Blut sein." As against all these authorities, Professor Lankester himself having made it a question of authorities by his using *ad augendam invidiam*, the word "notoriously," we have to set his statement unsupported by any record of independent investigation by himself of the structures themselves, to the effect that the vascular system of *Branchiobdella* "notoriously differs" from that of true leeches, "in that it *most certainly* does *not* eommunicate with the perivisceral cavity so as to form a lacunar circulation."

I have fastened upon Professor Lankester's employment of the word "notoriously," and I think that what I have said will "suffice to satisfy a conscientious bookmaker," or book reader, as to the value of the word as thus employed.

The question of fact is very readily stated, and if not very easily settled is yet capable of settlement by persons to whom *Branchiobdellæ* are available in the fresh state. It may be put thus: Does the simple unicavitary large perivisceral space of *Branchiobdella*, the homologue of the lymphatic system in general, and of that particular vasiform tritruncate modification of it which is found in so many leeches, differ from the lymphatic system or its homologue in nearly all other animals, if not all, with the exception of the *Chætophorous Vermes*, by not communicating with the blood-vascular system? I never thought that in the Hirudineæ, provided, as is "notoriously" the case in

Hirudo sanguisuga (Gratiolet, *Ann. Sci. Nat.* xvii. p. 199, 1862) and in *Piscicola* (see Budge in *Verhand. Nat. Vercin. Preuss-Rheinland*, vi. p. 112, and fig. 24, 1840, and Leuckart, *l. c.* p. 669), with a system either of smaller or larger tubes, bringing these vasiform specialisations of the perivisceral cavity continuously into direct communication with the blood-vascular system, there was any likelihood of, as there could be no need for, a lacuna existing to connect the two systems. But where, as in *Branchiobdella*, the perivisceral cavity has not been differentiated even into lateral and median vessels, not to say not into capillaries, and where the blood-vascular system proper itself remains in a condition of comparative simplicity, failing to develop a capillary system upon the walls of the intestine, and having its two great trunks connected by simple arches of anastomosis, the probability that a lacunar should exist, as in so many other cases, in supplementation of the missing capillary intercommunication, appears, as my above-given quotations abundantly show, to be very great.

If *Branchiobdella* is to be considered a leech, it is very strange that it should differ from its allies in not having its perivisceral system freely and openly communicating with its blood-vascular, the acknowledgedly existing difference that its perivisceral system is peritoneiform and not vasiform being a very much smaller difference, as the lacunæ of one genus are often enough replaced by vessels in an allied one. If *Branchiobdella* is to be considered one of the Annelides in the restricted sense, as it has, so far as I know, been for the first time proposed in Gegenbaur's 1878 edition of his *Grundriss der Vergleichenden Anatomie*, to consider it, I should still consider the question an open one so far as authority goes, following in this Professor Gegenbaur, who (*l. c.* p. 179) repeats the words used in the earlier edition of it (p. 198) and in the *Grundzüge* (ed. 1870, p. 234):—"Dieser aus einem lacunären system hervorgegangene Gefassapparat ist auf die Hirudineen beschränkt, denn bei den Anneliden ist die Scheidung des Gefasssystems von der Leibeshöhle fast durchgehend entwickelt. Wo sie fehlt, sind nicht Weiterentwickelungen, wie sie die Differenzirung der Leibeshöhle der Hirudineen bot, sondern Rückbildungen im Spiele." Now, I submit that the parasitic habits of *Branchiobdella* are, on general grounds, likely to have produced

such a readily-produced "Rückbildung" as that of leaving a vascular system open at one or more points. And as a third warning against rashly stating that the vascular system of *Branchiobdella* "most certainly does not communicate" with its perivisceral, I will draw attention to the fact that in *Malacobdella*, which, whether it be nemertine or leech, had anyhow been supposed to possess a closed system of vessels, whether homologues of lymphatic or of blood-vessels, these vessels have recently been shown by Professor Hoffmann (*Niederland Archiv. für Zoologie*, Bd. iv. 1, p. 9, 1877) to possess small round stomata in their walls. It is to be hoped that the question may shortly be set at rest by some anatomist to whom *Branchiobdella* is available in the fresh state, a state in which it is not very easy to transport it to any great distance.

Professor Lankester says:—"A glance at Dorner's excellent memoir on *Branchiobdella* would, however, suffice to satisfy a conscientious bookmaker that the vascular fluid of *Branchiobdella* has not yet been shown to contain corpuscles." I was not acquainted with Dr Dorner's memoir till Professor Lankester drew my attention to it in this article; since that I have not merely glanced at it, but studied it carefully. My study, however, of this memoir, combined with that of others treating of the same subject, has not sufficed to satisfy me that the blood of *Branchiobdella* does not contain corpuscles. Indeed, the one single passage relating to the interior calibre of the blood-vessels which I have been able to find in this memoir appears to me to *point* at least to the exactly opposite conclusion. This passage runs thus (p. 499):—"Eigenthumlich für das Gefass-system is noch eine Anzahl hinter einander liegender Körner, welche der Innenwand anliegen." For the presence of such granular bodies in such a situation is, to me at least, intelligible only on the hypothesis of their forming blood, and, from the analogy of such Annelides as *Cirratulus*, corpusculated blood for the contents of the vessels which they bestud.[1] Anyhow, Dorner's words, which state a positive fact,

[1] Keferstein (Müller's *Archiv.* 1863, p. 509) speaks of three *stripes* of finely granular pigment as lying upon the inner wall of the dorsal vessel of *Branchiobdella*, such as many other Annelides, *e.g.*, *Cirratuls filiformis*, previously described by him (*Zeitsch. Wiss. Zool.* 1862, p. 123, possess.). Similar stripes are figured by Claparède (pl. xxiii. fig. 3, B, p. 268), "Les Annelides Chætopodes du Golfe de Naples" from *Audouinia filigera*, and are stated by him (p. 265) to exist simi-

do not bear out Professor Lankester's suggestion of the negative conclusion proverbially, and here so specially, hard to prove. For, as regards the blood-vascular system of the leeches generally, Leuckart, who includes under them *Branchiobdella*, says (*l. c.* p. 670) :—"The blood of the Hirudineæ contains exceedingly few blood corpusles, and these, it should be noted, do not, as it appears, even circulate in every part of the vascular apparatus." Leuckart then proceeds to describe the various bodies which go by the name of blood-corpuscles in the leeches, with which animals he always classes *Branchiobdella*, and of the vascular system of which animals he takes *Branchiobdella* as a type a few pages back. Similarly Leydig, who repeatedly refers to the histology of *Branchiobdella* (*e.g.*, *Archiv. für Mikros. Anatomie*, i. p. 274, 1865; *Tafeln zur Vergleich. Anatomie*, pl. ii. fig. 6), and must repeatedly have had it, with its faintly coloured blood, under the microscope, as he tells us (*Zeitsch. Wiss. Zool.* i. p. 117, 1849) he has had *Piscicola*, so like it in this respect, writes of the blood-corpuscles of leeches without ever hinting that *Branchiobdella* which

larly placed either between the muscular coat of the vessels and the tunica intima, or in the substance of this last in *Cirrhatulus chrysoderma*. Both these animals have corpusculated blood, and it is difficult to think that the suspended granules, which, according to Selenka (*Niederland Arch. für Zoologie*, Bd. ii., 1874–75, p. 34), give the blood of *Aphrodite aculeata* its yellow tinge, do not come from some similar source. "Blutbereitende organe" of a very different morphology, but from homologous situations, are figured for us by Kupffer as the so-called "valves" in the dorsal vessel of Piscicola (*Zeitschrift für Wiss. Zool.* xiv. pl. xxix. A, fig. 3, p. 342), and by Leydig, from the homologous locality in the oligochætous *Phreoryctes Menkeanus* (*Archiv. für Mikroscop. Anatom.* i. 1865). The proliferation of the large cells, figured by these two authorities, into numerous small round non-nucleate bodies, which individually are scarcely half the size of the nucleus of the cells, is the source of many, but not of all, the smaller bodies visible in the blood of these animals. Retrograde, however, as well as other changes, count for much of the "Körnchenbildung" of the blood as usually examined, and good figures of such changes are given by Barry (*Phil. Trans.* 1840, pl. xxix. fig. 6) and by Gulliver (Gerber's *Anatomy*, fig. 268). The formation of lymph corpuscles by proliferation of the peritoneal endothelium was demonstrated by Schweigger. Seidel and Ludwig, in 1866, in Ludwig's *Arbeiten* (i. 180). Kölliker (*Gewebelehre*, p. 618, 1867) suggests that the like process may take place in the smaller lymphatic vessels. Remak (*Untersuchungen ueber Entwickelung*, p. 22) made the same suggestion, in 1855, as to the blood-vessels, and Leydig, in 1857, in his *Histologie* (p. 447), has the following words :—"Das sog Gefässepithel scheint ebenfalls durch Zellenwucherung die Zahl der Blutkügelchen vergrössern oder die etwas untergegangenen ersetzen zu können." (See also *Bau des Thierischen Körpers*, 1864, p. 67.) Dr Beale, in his *Microscope in Medicine* (1878, p. 259), pronounces himself to the same effect.

he, like Leuckart, considers to be one of the Hirudineæ, differed from them in this same cardinal point of the absence of corpuscles from its vascular fluid. Both, then, of these excellent observers consider *Branchiobdella* to be a leech; both repeatedly treat of its histology; both describe the blood-corpuscles of the Hirudineæ; neither ever suggests that these corpuscles are wanting to *Branchiobdella*, though one of them, viz., Leydig (*Archiv. Mikro. Anat. l. c.* p. 281), does assert this of *Chætogaster*, an animal, the somewhat similar habits, not to say structure, of which would have been likely to suggest a comparison.

One of the most surprising statements in Professor Lankester's paper is to be found on the first page of it (p. 68), and it runs thus :—"The fact, however, that abundant corpuscles are present in this same fluid" (the red vascular fluid of Chætopodous worms) "in the case of the earthworm (and, as appears very probable, in all similar fluids) has hitherto escaped detection, owing to the difficulties of observation which small corpuscles floating in a deeply-coloured liquid present, and also to the fact that the method by which they may be rendered apparent has not been applied to them by the various observers who have occupied themselves with this matter." It is difficult indeed to understand, and I shall not make any suggestions as to how Professor Lankester can have come to write this. Professor Wharton Jones, whose writings and views as to the morphology of blood-corpuscles are referred to in every text-book, for example, in the latest edition of Quain and Sharpey and Schäfer, 1876 (p. 42), as "supported by Busk, Huxley, and Gulliver," has devoted an entire page (p. 94) of the *Philosophical Transactions* for 1846, the volume containing the memoir thus currently quoted, to the blood-corpuscles of the earthworm. Amongst many other objects which Professor Wharton Jones records as having been procured by him from the blood of the earthworm, he mentions "corpuscles altogether like the nucleus and its surrounding granulous mass" of certain nucleated cells "both in form and size." This "cellæform nucleus is about $\frac{1}{3600}$th of an inch in diameter, with a finely granulous mass surrounding it." Professor Lankester describes the corpuscles of the earthworm as follows:—"They are flattened fusiform bodies, usually somewhat broader at one end than the other, sometimes nearly circular. They vary

in size from the $\frac{1}{3500}$th to the $\frac{1}{2000}$th of an inch in long diameter, but by far the majority are of a uniform length of about $\frac{1}{3000}$th of an inch. The corpuscles have a clean, sharp outline, but occasionally what appears to be a small quantity of ragged protoplasm is seen beyond this sharp contour." Professor Lankester has not, in this paper, given us any figures of the corpuscles thus clearly described. When his promised figures do appear, it will be interesting to compare them with the descriptions and figures given (*l. c.*) by Professor Wharton Jones.

Secondly, in the year 1852, Professor Ecker, in the third plate of his *Icones Physiologicæ* (fig. 21), figures the blood-corpuscles of the earthworm under three denominations, viz., firstly (*a*, *b*, and *c*), "Körperchen mit vielen Vacuolen und staehlichen Fortsätze, die Form und Stelle wechseln; die Hohlräume mit gelblichem Schimmer," which amæbiform bodies I believe to be perivisceral in origin; secondly (*d*), "Kerne," one variety of which is granular, and the other hyaline as to its contents; and thirdly (*e*) "Feine Körnchen," which till lately I held to be the only formed elements existing in the worm's red fluid. But the two kind of bodies figured by Ecker at (*d*) are to be found in this fluid, when uncontaminated with perivisceral fluid, and before its morphology is upset by the setting-in of those changes to which all fluids containing colloids are so liable under the influence of so many disturbing agencies.

Thirdly, in the year 1835 we find Rudolph Wagner (Müller's *Archiv.* 1835, p. 313) asserting a claim to having seen the blood-corpuscles of the earthworm in 1832, and vindicating himself against an expression of surprise uttered by the elder Carus, in his *Lehrbuch der Vergleich. Zootomie* (ii. p. 682, 1834), at his not having discovered the "deutlichen runden abgeplattiten Blutkörperchen im rothen Blute des Regenwurmes."

Fourthly, Leydig's words (*Histologie*, p. 437, 1857), "Zu innerst sah man hoch vereinzelte blasse Kerne die wahrscheinlich von Blutkügelchen berrührten," appear to me to apply, even when I take the sentence in its own context alone, to the earth worm; and when I recollect that it was Leydig who pointed out (*Archiv. für Mikroskop. Anat.* i. 281, 1865) that *Chætogaster* has no blood-corpuscles, I cannot but think that he would have made here the same remark as to *Lumbricus* if he had not seen it to be

otherwise conditioned, and, indeed, had not supposed himself to have stated the fact to be so.

Fifthly, I have to say that in the year 1861 the late Dr John Davy read a paper before the British Association at Manchester on "The Blood or Red Fluid of the Common Earthworm." This paper is printed *in extenso* in his second series of *Physiological Researches* (1863, p. 203-207). In it Dr Davy states that I assisted him "especially in laying bare the cardiac organs, and in procuring their contents." "Indeed," he adds, "it was at his request that the inquiry was entered upon." He then gives at some length an account of the method we employed for collecting the contents of the vascular system, so as to keep them free from admixture with the perivisceral fluid; the essentials of the method being that a delicate pipette with, at one end of it, a very thin bulb, and a sharp perforated point at the other, was used for puncturing the great vessel, and extracting from it "one or two small drops, varying with the size of the Annelid and its condition." "The dissections were conducted under water; and before the cardiac organ was opened, which was done out of water, the fluid which bathed the vessel was carefully washed away, and the surface of the vessel was wiped with bibulous paper." Dr Davy describes the bodies seen in the red fluid thus obtained as follows:—"Viewed under the microscope with a one-eighth inch power, granules or minute corpuscles were seen scattered through it. These varied a little in size; their average size was about $\frac{1}{14000}$th of an inch, or about one-fourth that of the blood-corpuscles of man. Each corpuscle had a luminous centre and well-defined outlines faintly coloured red, or yellowish-red. The colouring matter, it was pretty clear, was contained within the cell. After some doubt and many trials, this was the conclusion we arrived at—that the fluid owed its colour, either altogether or in great part, to those corpuscles." I did not at the time entirely agree with Dr Davy's views, the exceedingly small size of these bodies making me averse to calling them by the same name as any indubitable "blood-corpuscles" of Invertebrata; whilst two non-quantitative peculiarities observable in many of them compelled me to consider them "lifeless," in a more thorough-going sense than it has ever been proposed to consider even the Mammalian red blood cell. These two pecu-

liarities were, firstly, the presenee in many of these spheroids of coneentrie striation, reminding one of the similar lines in the mueh larger amyloid bodies from the prostrate and the walls of the eerebral ventricles; and secondly, the oecupation of the eentre of many of them by a rough-hewn, solid, and therefore functionless, dot of yellowish-red pigment. These coloured bodies are strikingly like the pullulations produced in Mammalian, and other red blood-corpuseles, by the aetion of tannin, deseribed by Dr Roberts. I thought then, and know now, that a large proportion, if not the whole, of these bodies were due to retrograde metamorphosis; and knowing then that the more care (we took too mueh eare) was taken to exelude the possibility of any intermixture of periviseeral fluid, the smaller was the number of any other elements in a mieroscopie slide of the red fluid of the worm, I, after some deliberation with myself and others, deeided to speak (p. 124) of this fluid as being "non-corpuseulated." Similarly Dr A. Rollet, the author of the artiele "Blood" in Stricker's *Handbook*, had said (*Sitzungsb. Akad. Wiss. Wien.* Bd. xliv. 2, 1861, p. 630) of a drop of the worm's red fluid that he never found anything like a red eorpusele in it. The real history of these bodies may be given by saying that they are due to the breaking up of true blood-eorpuseles, by a proeess which brings to an end the interpenetration of their "zooids" and "œcoids"; in other words, their genesis is as artificial as that of the similarly minute "Zimmermansehe Körperehen" in human blood. The way in which I have been led to see this is as follows:—Mr W. Hatehett Jaekson, Demonstrator in the Oxford University Museum, suggested to me that instead of discharging the red fluid from a capillary pipette on to a slide, and so examining it as Dr Davy and I had done in days before immersion lenses were known in England at least, we should examine it whilst still eontained in the pipette and under Hartnaek's immersion 10, coagulation occurring very imperfeetly, as Professor Schäfer has shown it to do, with frog's blood similarly treated. The red fluid of the worm can thus be seen to possess many true eorpuseles, of various sizes, some with homogeneous, some with granular contents, and some with one or more of the solid coloured bodies mentioned above plaeed either intra- or extra-globularly. The pipette also draws out of

the vessels masses of coherent cells, which in their shape and in the variability of their size resemble many of the free cells, but which always have their contents homogeneous. These masses, like the closely similar aggregations figured by Kupffer (*Zeitsch. Wiss. Zool.* xiv. Taf. xxix. fig. 3, *a*, *b*, and *c*), are, no doubt, the product of the proliferation of the blood-vascular endothelium. If the pipette has been cleanly plunged into the vessels it will not be found to contain any of the large amæbiform or other corpuscles which some authors have ascribed to the blood of the worm. If the red fluid is purposely or accidentally mixed with water, the appearance described by Dr Davy takes the place of appearances such as Claparède has figured (*Annélides Chétopodes du Golfe du Naples*, pl. xxvi. fig. 1, G), from the still living blood-vessels of one of the Opheliæ which in some other respects resembles the Oligochæta.

A more instructive confirmation of the view which regards the minute granules in human blood, known as Zimmermann's bodies, if not those figured by Schultze (*Archiv. Mikr. Anat.* pl. i.) as being, in opposition to the views of Zimmermann himself, to whom we owe so much of our right views as to fibrin, mere "Detritus-bildungen," I cannot conceive than that which is furnished by the watching of the falling to pieces of the lumbricoid corpuscles under the disturbing action of the addition of water, or, though to a less degree, under that of the transference from a glass vessel such as the capillary pipette to the wider contact of glass constituted by the slide and cover.[1]

[1] Since writing as above, I came, by following up a reference of Virchow's (*Cell. Path.* ed. 1871, p. 240), upon the following passage (Virchow's *Archiv.* i. p. 389), in which that observer, in describing the separation of the coloured elements from the rest of the blood-corpuscles, writes as follows:—"Sowohl bei dieser Entwickelungsweise, als da, wo das Hämatin zuerst an Faserstoffgerinnsel, etc., getreten war, sieht man in dem Maasse, als die Körner schärfer hervortreten, am Rande eine farblose Substanz erscheinen, die nicht selten, ähnlich einer Zellenmembran, die Körner umschliesst. Indess habe ich mich nie überzeugen können, dass dieser Saum etwas anderes, als eine homogene Substanz sei; er zeigt keine der Eigenschaften, welche als Kriterien für eine permeable, vom Zelleninhalt trennbare Membran gelten dürfen, und ich muss daher *Gluge* beistimmen, wenn er sagt (*Atlas der Pathol. Anat.* Lief. iii. Melanose, p. 4): 'Oft werden die unregelmässigen oder viereckigen schwarzen Massen nur von einer membranösen Unterlage (die wahrscheinlich durch coagulirten Faserstoff gebildet ist) zusammengehalten, und als dann erscheint eine dünne Lamelle unter dem Mikroskop, wie Schildplatt.'" Remak, in his *Entwickelung der Wirbel-*

It is possibly even more interesting to remark how closely parallel is the behaviour of alumina, and some other inorganic substances, to that of the sanguigenous colloids which we are dealing with; 'soluble alumina," says Professor Graham (*Phil. Trans.* 1861, p. 207), "is one of the most unstable of substances—a circumstance which fully accounts for the difficulty of preparing it in a state of purity. It is coagulated or pectized by portions so minute as to be scarcely appreciable of sulphate of potash, and, I believe, by all other salts, and also by ammonia. A solution containing two or three per cent. of alumina was coagulated by a few drops of well water, *and could not be transferred from one glass to another, unless the glass was repeatedly washed out by distilled water, without gelatinising.*"[1]

thiere (1855, p. 22–23), gave a similar explanation of the nature of the so-called "Blut-inseln," speaking of them as "Zufällige Anhaufungen von Blutzellen welche durch geronnen Faserstoff zusammengehalten und eingehüllt sind." I incline, however, to think that the concentric striation observable round the pigment nodules above mentioned may be due to the rearrangement of the "œeoid" after the central concentration of the "zooid," which is then surrounded by it much as a rocky islet may be seen at low water to be surrounded by a zone of smooth sand.

[1] The late Professor Max Schultze, in his article in the first number of his *Archiv. für Mikroskopische Anatomie* (1865), whilst observing that "im Blute ist gewiss kein Bestandtheil gleichgultig," (p. 36), and discussing the import of the "Zimmermannschen Körperchen," adds that they have been left unmentioned in the recent handbooks of microscopic anatomy. It may be worth while, therefore, to supply here certain references to memoirs which treat of them, and bodies closely allied to them, and which, with the exception of those by Zimmermann himself, mostly point to their being properly regarded either as *arte facta*, or as morbid, or as *post-mortem* products:—

Zimmerman.—Rust's *Magazin für Gesammte Heilkunde*, 1846–48, Bd. 66, p. 173.
Virchow's *Archiv.* xviii. p. 221, 1860.
Zeitschrift für Wiss. Zoologie, xi. p. 344.

Virchow.—*Archiv.* i. p. 389, 1847.
Cellular Pathologie, 1871, pp. 193–266, where these bodies are spoken of as "Trümmer and Bruchstücke alter Blutkörperchen."

Schultze (*l. c.* 1865, p. 38–41) recommends further investigation into the nature of the several "Körnchenbildungen" in blood, not considering them to be all alike either *arte facta* or what Mr Gulliver has called the "molecular basis of the chyle."

Böttcher.—Virchow's *Archiv.* xxxvi. p. 414, *seq.* 1866.

Hensen.—*Zeitschrift für Wiss. Zool.* xi. p. 259.

Beale.—*Microscope in Medicine*, 1878, p. 263–4.

Rollett.—Stricker's *Handbuch*, 1869, p. 300, or p. 413 English translation.

The "minute spherules" described by Mr Gulliver (*Gerber's General Anatomy*, pp. 10, 23, 24, 25 Appendix, and fig. 268) appear to be identical with the "Zimmermansche Körperchen," and from his account of them, as also from that given by Martin Barry of the blood, figured by him (*Phil. Trans. l. c.*), we may gather that they are produced in special abundance in altered or altering blood.